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The Earth as seen from Apollo Seventeen.
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Washington, D.C., April 1987

EXECUTIVE SUMMARY

Linking Remote-Sensing Technology and Global Needs: *A Strategic Vision*

A Report to NASA by the Applications Working Group

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Overview

In the scant 30 years since the first civil satellite was launched into space, remote sensing has profoundly affected our knowledge of the planet Earth—its continents, oceans, atmosphere, biosphere, and ice cover. We have discovered a far more dynamic and complex world than could be imagined only a few generations ago. Remote sensing is expanding mankind's vision of the Earth and of how our air, land, and oceans interact on a global scale. Such interactions affect climate and provide clues to the actions that can and must be taken if mankind is to survive and flourish—to preserve the quality of our air, the limited natural resources essential to our quality of life, and to extend the food supply of an expanding world population. From satellite observations of the Earth, we are now able to

- Make 3- to 5-day worldwide weather forecasts over most parts of the globe, with accuracy and coverage never before possible
- Monitor drought over large regions of the Earth, such as the African Sahel
- Measure forest fires and deforestation over millions of acres of sparsely inhabited and wilderness terrain
- Pinpoint the bioproductive ocean areas most likely to harbor feeding fish
- Use ground tracking of satellites to verify the annual shifting of the Earth's tectonic plates, potentially helpful for predicting earthquakes

The extraordinary progress made in space technology has outstripped our ability to use and apply this knowledge. The help that could be available from remote sensing is barely being tapped on a myriad of practical issues—land management, short-term climate forecasting, ocean resource development and management, marine operations, urban planning, crop and forest yield predictions, and oil and mineral resources.

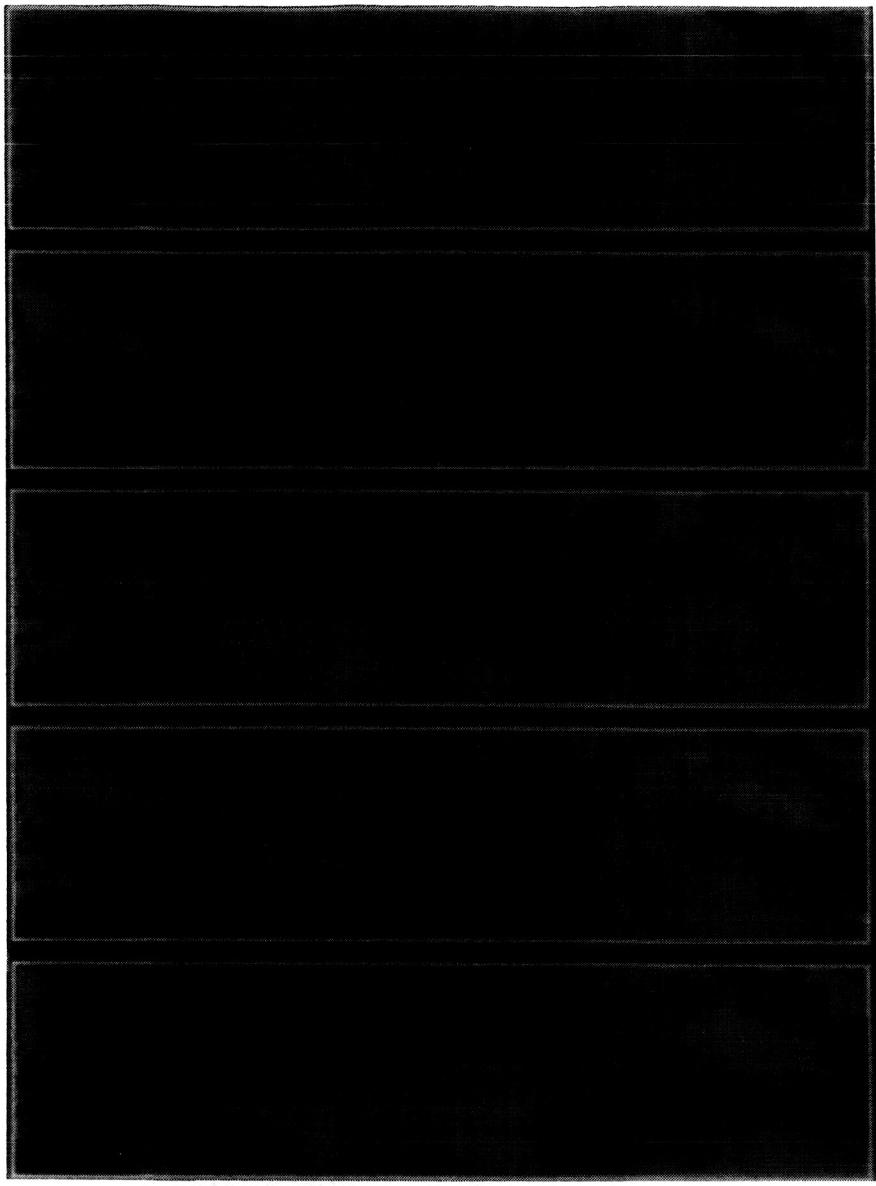
The United States, with its huge initial investment in space technology, has led the world in pioneering the development of this field. But we are not reaping its full potential benefit. In fact, we are now in danger of losing our premier position, as other countries move aggressively to utilize the technology more effectively than we are doing. As seen in newspapers worldwide, highest resolution images of the nuclear disaster at Chernobyl came not from a U.S. satellite, but from the new French commercial satellite, SPOT. Japan and India now operate their own Earth satellites; both have enunciated a national goal of using these satellites to exploit the natural resources of the Earth for the benefit of their countries.

Recognizing the importance and enormous practical value of information now being generated by remote sensing of the Earth, Congress directed NASA in the FY 1984 Authorization Act to develop a long-term strategy and plan for their applications program "to ensure that the Nation is investing sufficiently and wisely" in this important area. This Executive Summary highlights the views and strategies developed by a working group of technical advisors invited by NASA to participate in planning such a strategy.

The methodology used by the Working Group was to develop a long-range strategic goal for guiding NASA's applications program and then to define the technical steps to achieve this goal by developing near-term research objectives. These objectives are examples of needed, high priority applications research. The number and extent of applications projects actually carried out by NASA will depend on available funds and many other factors.

The full report of the Applications Working Group appears as Part Two of this series. The report represents a strategic approach rather than a complete plan. It is designed to provide a realistic vision for fostering remote-sensing applications, near-term milestones to help NASA focus its priorities for research, and guidelines for evaluating applications proposals.

To implement the report as suggested by the Working Group, NASA will need to set up new institutional agreements and relationships with other agencies and to seek advice from the user community. The report, then, is expected to be used by NASA as a basis for developing the complete NASA plan, including implementation strategies, working agreements, schedules, and budget requirements. As an outcome of the report, NASA would solicit applications research proposals from universities, industry, operational agencies, and the scientific research community. The report is intended as a strategy to guide NASA's priorities, not as a national plan.



SEA SPACE

1979

1980

1981

1982

1983

Movement of heat by winds and ocean currents over the globe plays an important role in changing weather and climate patterns. Tropical Pacific sea-surface temperature patterns, averaged over each January for 5 consecutive years, are shown in these Scanning Multifrequency Microwave Radiometer images. Note the striking absence in 1983 of the cool tongue of water (in blue) normally found along the equator. The 1982-83 images reflect the strongest El Niño of this century.

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Applications Program Strategy

By the mid-1990s, with the advent of the Space Station Polar Platforms carrying a combined load of research and operational sensors, an avalanche of raw data will pour down to Earth. Scientists will use this flood of information to look at such basic questions as how Earth systems operate, how man-made pollutants affect Earth's protective ozone layer, and how rainfall in the tropics affects global climate. Such knowledge has enormous long-term benefits for life on Earth.

Can we make these data available not only to scientists but to the thousands of individuals, companies, and government groups who could use it? Its usefulness is legion—for the local irrigation district managing watershed problems, for the forest firm using a microcomputer to predict forest yields, for the shipping company concerned with both safety and fuel savings, for the fisherman hoping to increase his catch for the day. The payoff from the investment being made in space technology will come from our ability to provide information that meets such practical needs as these.

THE GOAL: A STRATEGIC VISION

Remote sensing has changed our perception of the Earth, helping us to understand that the Earth operates as an integrated global system. But many kinds of sensor data are not yet available to potential users. The Working Group is convinced that the key to expanding applications lies with broader access to information. Data transmitted from space must be interpreted into meaningful information. This requires the development of algorithms and models, and demonstrations that verify the accuracy and interpretation of remotely sensed data as compared with ground measurements. Above all, information systems must be developed that will allow users easy access to the information they need.

The vision for the future is an Applications Information System available to all users—whether a large government agency or a small local firm—that will provide overall benefits for the public good and further the economic interests of the United States. As a first step, the Working Group proposes as its overall goal *"to develop and demonstrate, by the end of the next decade, integrated information systems that will allow private industry, operational agencies, and scientific research communities to exploit effectively the data taken by Earth observing satellites."*

This projected Applications Information System would be designed to fit as one part of the integrated Earth sciences information system now being planned by NASA for Eos, the Earth Observing System of the 1990s. The information system concept is therefore not new. It simply introduces the applications agenda into the planning for NASA's new information system, which is expected to integrate both scientific and operational data as well as pertinent data from other sources.

Plans were predicated on the following crucial operating assumptions:

- There will be an operating Space Station beginning in the mid-1990s.
- Roles and missions of government science agencies will remain as legislated and as currently performed.
- Operational remotely sensed data will continue to be available.
- NASA's Earth Science and Applications Division programs will continue to be science-driven.
- The budget of NASA's Office of Space Science and Applications will remain relatively constant.

Timeliness of the Strategy

The time is right for developing an Applications Information System. Space technology has reached an appropriate level of maturity to warrant such a step. During the 1960s and 1970s, the United States made extraordinary progress in developing both spacecraft and sensors that permitted global observations of the Earth's surface, ocean, and atmosphere from space. NASA's research satellites Landsat and Seasat showed the enormous potential of this technology. Polar-orbiting weather satellites became operational in 1966, and geostationary environmental satellites were launched in 1974.

The science of remote sensing has emerged and grown during the 1980s, with emphasis focusing on the development of improved statistics and more sophisticated models, particularly two- and three-dimensional numerical models. New four-dimensional models reflecting time can now be constructed, which will help us to understand the interactions at such boundaries as those between atmosphere and ocean. Advancement in computer technology, combined with satellite and in situ observations, is making possible the development of these ever more sophisticated global models. Data management systems can now be created that are capable of handling large quantities of interdisciplinary and multidisciplinary data.

By the 1990s, with launch of the Polar Platforms providing continuous data streams, it will be possible to understand and transfer a wide range of Earth science findings into the practical domain. In the coming decade, the usefulness of remotely sensed data will be limited not by technology, but by user access to the data collected in space.

The proposed integrated system would provide not just general access to research and operational data, but would ensure that appropriate, helpful calibrations, algorithms, and models are available to users. The system would also foster development of remote-sensing products.

THE OBJECTIVES: STEPS TOWARD THE GOAL

Building an Applications Information System accessible to a wide range of users needs to be done incrementally, not only to stretch out costs in the current budget climate but, more important, to provide a chance to test and fine-tune the system as users access information. To demonstrate the feasibility and usefulness of the projected information system, only a limited number of high-priority applications objectives could be selected. These objectives were chosen so that, in toto, they would demonstrate the following important characteristics:

- Capacity to meet the needs of all types of applications users, including the research community, operational agencies, and end users (individuals, companies, the value-added industry, government entities)
- Capacity to provide near real-time data for the operations community, slightly delayed and historical data for researchers and end users, and related types of data for all users
- Capacity to provide useful applications pertaining to all Earth science disciplines, particularly from land, ocean, and atmospheric sensors
- Potential for gaining useful scientific knowledge from the applications demonstrations, deriving synergistic benefits for both science and applications

Although five applications objectives were chosen to demonstrate separate modules and capabilities of the proposed information system, each also stands as an important demonstration in its own right, representing critical issues of strategic and human importance. Each is a topic of high national or international priority,

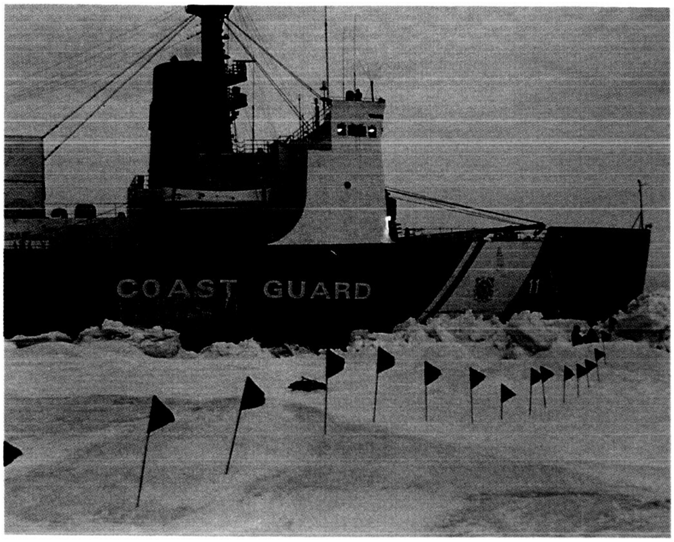
worthy of immediate and concentrated attention and capable of showing significant potential gain from remote-sensing techniques.

Renewable/Nonrenewable Resources Objectives

In the renewable/nonrenewable resources areas where there are no large operational satellite systems, users are expected to include many individuals, small companies, and university researchers using microcomputers. The resource areas depend heavily on imagery and require demonstration projects before the techniques for extracting information can become operational. The chosen objectives focus on the following:

- *Renewable Land Resources*—Define and validate by 1995 new information systems that support global mapping of arable land degradation every 5 years, showing losses due to erosion, salinization, and desertification
- *Renewable Forest Resources*—Define and validate by 1995 new information techniques that support global mapping of forested versus nonforested areas every 5 years, with local sample mapping of forest production and yield estimates for the four major types of forest ecosystems
- *Nonrenewable Strategic Resources*—Develop and validate by 1993 new data management systems and information extraction techniques for evaluating the potential occurrence of strategic, nonrenewable raw materials on a global basis, specifically the chromium, cobalt, manganese, and platinum-group metals needed to manufacture high-technology products

These particular objectives are serving as test cases. The remote-sensing techniques being demonstrated, if they prove successful, can be broadly applied to other applications. For example, four strategic raw material groups have been chosen to test whether their potential occurrence can be shown by use of remote sensors combined with conventional data. If the technique is successful, it can be applied to other minerals and would presumably be used on a routine basis in the latter 1990s after launch of the NASA/NOAA Polar Platform.



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Ocean/Atmosphere Objective

Regarding the ocean/atmosphere, the objectives are similar; these areas have a longer remote-sensing history with several operational agencies already in place, such as the National Oceanic and Atmospheric Administration (NOAA), the Navy's Fleet Numerical Oceanography Center (FNOC), and the Air Force Global Weather Central (AFGWC). For these objectives, NASA will play an intermediate role by providing gridded, digitized data and high-rate data links for sharing computational facilities among various centers. During the initial and demonstration phases, users will be operational agencies, major government and university research programs, and the international community. End users will include the commercial market for weather services, the fishing and shipping industries, search and rescue missions, pollution management, and the value-added and offshore industries. The following objectives were chosen for the ocean/atmosphere areas:

- *Ocean—Hindcast, Nowcast, and Forecast*—Define and validate by 1995 an operational hindcast, nowcast, and short-term (up to 1 week) forecast system, with mesoscale resolution, for such important physical variables in the oceanic and atmospheric planetary boundary layers as wave height, ocean surface and atmospheric temperatures, currents, and surface winds
- *Atmosphere—Four-Dimensional Data Assimilation*—Develop and validate by 1993 a global research atmospheric system for weekly, monthly, and seasonal values of such climate parameters as temperature, humidity, wind components, soil moisture, ice and snow cover, precipitation, and surface and atmospheric albedo

The ocean/atmosphere objectives are designed to provide technical advances in long-range weather and short-range climate forecasting capabilities. The approach incorporates a number of new parameters, particularly wind and wave height data, that will soon become available with the launch of the Ocean Topography Experiment (TOPEX) and NASA's scatterometer on the Navy Remote Ocean Sensing System (N-ROSS).* The approach uses in situ data that will be collected by international research programs, such as the Tropical Ocean Global Atmosphere program.

This objective also helps to define NASA's ongoing technical role within the operational system, specifically in interfacing research data and in putting the data into an assimilated data system. This interface, which occurs primarily with NOAA, is dealt with in the report as a technical rather than a political interface.

For each objective, a plan has been developed to guide NASA over the near term. These plans specify measurement and model requirements, information systems requirements, demonstration projects and schedules, and technology transfer objectives and recommendations. The outcomes of each demonstration—the data, algorithms, and models—will become modules in the planned, evolving information system. More detailed information appears in Section 4.

RECOMMENDATIONS FOR IMPLEMENTATION

This applications strategy reflects the urgent needs voiced by potential users of remotely sensed data. Because these users represent such a diverse, dispersed group, they frequently remain unaware of how they could profitably use or access such data. For this reason, the applications strategy needs care not only with its content but with how it is implemented. The Working Group makes the following suggestions to NASA for implementing the long-range applications strategy.

1. NASA should immediately state its intention to support remote-sensing applications research activity and to demonstrate its commitment by issuing a call for proposals.
2. NASA should develop mechanisms to involve users heavily in its R&D program and to state this intention publicly; users should be involved at all stages from inception through implementation.
3. NASA should encourage the use of interdisciplinary data in its applications R&D program, including support to help users and the research community as they develop both an awareness of such data and expertise in its accession and use.
4. NASA should plan early for the overall engineering concept of the Applications Information System, so that both the system's initial development and its evolution will be aligned with the needs of the individual disciplines.
5. NASA should establish an Information System Oversight Group representing the disparate user community to ensure coordination, maximum usefulness, and standardization of the system design.
6. NASA should promptly address the major management issues that must be resolved in order to establish an Applications Information System.
7. NASA should promptly adopt and implement the evaluation criteria contained herein and use them in evaluation of the applications proposals.

* *The Applications Report was developed before the cancellation of N-ROSS, but NASA is still planning to fly the NASA scatterometer (NSCAT) in the early 1990s.*

Environmental Research Institute of Michigan

Salt accumulating in the soil of irrigated lands (red) is severely affecting crop production along the Indus River (upper left) in Central Pakistan, shown in this Multispectral Scanner (MSS) image.

Environmental Research Institute of Michigan

Croplands most needing reclamation through selective leaching can be identified in this September-December multitemporal MSS image (green/yellow show affected croplands; orange/red show areas not severely affected).

3

Benefits of the Applications Strategy

An inherent challenge of the U.S. space program is its dispersion. Remote-sensing operations are scattered among many Federal agencies, including not only NASA but the Departments of Commerce (NOAA), Defense, Energy, Interior, Agriculture, and others. NASA contains not only the most advanced technological and engineering expertise available in the world, but equally strong research capabilities in the Earth sciences. What is missing are the institutional and procedural links between NASA's research capabilities and other Federal agencies, as well as access to this repository of information by outside users.

The proposed information system provides a viable structure for linking NASA's research strengths to Federal operational systems and to outside users. The networking of the information system provides such linkage by both its nature and design. In addition, in the planning and operating of an Applications Information System, NASA would have a vehicle for regularly receiving the current perspective of applications users.

ATTRIBUTES OF THE STRATEGY

Virtually all national and international bodies in the Earth sciences are now calling for a new, integrated approach to studying the Earth. Within this context, a highly significant activity is the initial report of the Earth System Sciences Committee (ESSC), which was established in 1983 by NASA's Advisory Council. The ESSC mission, now nearly complete, is to review the science of the Earth, to recommend an implementation strategy for global Earth studies, and to define NASA's role within such a program.

The proposed Applications Information System is not only consistent with ESSC recommendations, but complements the ESSC report by focusing on specific applications issues addressed only in broad scientific terms within that document. The global systems approach proposed by ESSC includes the following recommendations to NASA, all of which form a valuable and essential framework for the proposed applications strategy:

- The Earth needs to be understood as a single, interrelated system, with research attention given both to the separate research disciplines and to how the major geophysical domains (biota, atmosphere, and oceans) interact
- The study of global change requires an integrated research program based on long-term, continuous global observations of the Earth
- An advanced information system will be needed to enable the international scientific community to process global data and to permit efficient data analysis, interpretation, and quantitative modeling of Earth systems processes
- Worldwide study of the Earth will necessitate strengthened coordination among researchers of many countries, as well as collaborative international agreements

NASA's Earth system science plan and the proposed applications strategy have in common a similar program philosophy, shared observing system requirements, a need for historical archives, and a need for access to an information system at multiple levels that contains algorithms and models. In applications, there can be a requirement for either real-time data or for the longer term, delayed-time data usually used in scientific study. However, scientists may also benefit from access to real-time data that are not currently archived by the operational systems. The proposed applications strategy establishes particular sets of real-time data to be targeted for archiving and retrieval—information of value to scientists as well as applications users.

Real overlap also exists between the proposed applications objectives and areas of current concern to science. Knowledge gained from the proposed applications demonstrations can benefit scientists in all areas proposed for study, including the following:

- Land degradation—impact of varying vegetation on surface energy and the interactions of man-land-surface processes with climate in specific biomes
- Forests—land use and biome productivity, effects of deforestation on long-term climate

U.S. Department of Agriculture

U.S. Department of Agriculture

Satellite imagery can monitor change in vegetation conditions on a county wide to global basis, useful for such applications as assessing the spread of plant disease and forecasting of crop yields.

- Strategic minerals—use of remote sensing for identification of surface materials and to provide insight into the tectonic and geochemical processes that shape the Earth's crust
- Ocean—issues of large-scale ocean circulation on and below the surface, including how the atmosphere takes up heat and surface moisture from ocean surfaces and how this affects climate
- Atmosphere (climate)—the defining of climate state and its anomalies, using retrospective data and data delivered too late for daily forecasts

APPROPRIATENESS OF STRATEGY IN LONG-TERM NASA PLANS

The proposed applications strategy both complements and balances the ESSC report, which will be used to guide NASA's long-term scientific directions. The applications objectives represent shorter term, urgent problems with substantive scientific content. The strategy serves to focus short-term NASA priorities and to provide a structure for ongoing application projects within research planning of the Office of Space Science and Applications (OSSA).

The proposed Applications Information System offers significant advantages for the broader OSSA program. These include

- Practical assistance in guiding the evolution of the Eos information system now being planned. The Applications Information System is a precursor to and compatible with the planned Eos system.
- Responsiveness to the recommendation of all NASA's advisory committees for an integrated data base system that can provide widely dispersed access to multidisciplinary information for both research and applications purposes.
- Experience useful in preparing instruments for the Space Station Polar Platform, the chief vehicle for research and operational programs in the mid-1990s. Although the applications objectives were not designed to justify any particular measurement program, the planned demonstrations do in fact require the type of sensor measurements planned for deployment on the Polar Platform.
- Identification by application users of areas where new technology or techniques are required, which will help NASA in their advanced planning of new and improved instruments.
- Flexibility of the proposed system, as a result of its modular structure, for allowing NASA to achieve particular goals or milestones. Timing is less important than the overall concept, so that the number and schedule of applications modules can be varied.
- Adaptability of the strategy to fit NASA's budget constraints, also permitting the shifting of priorities to take advantage of potential new applications opportunities and needs as they arise.
- Definition of an ongoing research role for NASA within the large NOAA/Navy/Air Force operational systems.

NASA's applications strategy will also encourage and support use of remotely sensed data by the private sector. Individual firms need research help to interpret data from space and develop meaningful algorithms and models—such help will be engendered by cooperative proposal efforts combining university with private ventures. Users who participate in the program will become familiar with and attuned to using and merging geocoded, digitized data.

As a much broader community is introduced to the information obtainable from space, demand for such services will increase. The demonstrations themselves, along with later access to the information system, will enhance the commercial viability of all remote-sensing enterprises. This expanded user base will certainly benefit the EOSAT Company, set up to commercialize the U.S. land remote-sensing system, as well as the value-added industry (private companies that market their expertise in interpreting satellite data for specific business purposes).

4

Near-Term Applications Objectives

Important, concrete advances can be made relatively quickly in the practical use of remotely sensed data. To demonstrate the usefulness of sensor data over the near term, the Working Group selected topics in the four major sectors serving the user community: renewable resources, nonrenewable resources, ocean, and atmosphere. Of the myriad possible questions that could be addressed by global data, the Working Group decided to focus on five objectives: land degradation; global forest distribution and local forest production/yield estimates; occurrence of strategic mineral resources; ocean hindcast, nowcast, forecast system; and atmosphere (climate) four-dimensional data assimilation.

Each topic requires the collection of data, development of algorithms and models, in situ testing and demonstration, and transfer to users. All make use of both existing remote-sensing instruments and of experimental new instruments planned to be in use by the mid-1990s. By 1996, the outcome of these projects—the tested data, algorithms, and models—will be available to users as modules in the planned, evolving information system. The architecture of the integrated Applications Information System is based on the configuration of the four subsystems that will result from the demonstrations.

RENEWABLE/NONRENEWABLE RESOURCES

World population growth places ever-heavier, expanding demands on the finite resources of the Earth—on its land, fish and wildlife, and nonrenewable reserves of gas, oil, and minerals. Today, our efforts to meet global human needs must depend on continued technological progress. Land degradation, forest production, and identification of strategic mineral resources were chosen as topics over many other pressing issues, including arctic areas, cereal grains, marine fisheries, mountains, and wetlands.

For each resource objective, the state of current technology and the user environment molded the design for the planned demonstrations and the ensuing prototype information system. Because no satellite operational system managed by government agencies pertains in the land resources area, the data to be extracted could be repetitive but not continuous in nature, and the users would be a very widely distributed community.

Many of the needed space and nonspace data sources are either already in place or, in the case of remote sensors, will be flying experimentally in the 1990s. The practical use of land remote sensing has been hampered not by available technology, but by the lack of models and accurate, efficient algorithms. Also, the potential users of land remotely sensed data, coming from many fields with varying levels of sophistication, do not have ready access to in-place data bases either electronically or by mail. Plans in the resources area therefore stress the following:

- Merging of satellite data with many other types of disparate data sets, all geocoded and digitized
- Development and definition of models and algorithms for extracting information, cataloging, and retrieval
- Encouragement of combined research efforts by the academic community with the private and government sectors
- Design of an information system compatible with microcomputers, providing easy and economical access to individuals and small users

Objective: Renewable Land Resources

The objective by 1995 is to provide global mapping of arable land degradation every 5 years, showing losses due to erosion, salinization, and desertification with an accuracy to within 10 percent. Local site maps will be made at scales of 1:24,000 to 1:100,000 and global maps at 1:5,000,000.

The global supply of arable land available for food, fuel, and energy continues to decrease while world population expands and microclimatic change occurs. To better manage productive land, we need to gain improved global knowledge about where it is, what

Land Degradation Demonstration

The Steps

1988-1990: Initial Data Collection/ Data Base Construction Phase

- Define nine test sites (three each for salinization, desertification, and erosion implemented sequentially, one topic per year)
- Compile data bases of in situ and remotely sensed data, including remotely sensed maps of degraded land
- Develop algorithms for identifying, delineating, and quantifying degraded land, using existing data
- Formulate models of degradation processes
- Collect global data using Landsat's MSS* and TM* and NOAA's AVHRR;* prepare global maps of salinity, desertification, and erosion in 1990, to be updated at 5-year intervals

1989-1991: Information System Development

- Develop and implement the prototype information system (remotely sensed maps of degraded land, data base, models)
- Test prototype information system on local sites (1990-1991)

1991-1995: Demonstration Phase

- Demonstrate tools and techniques for land degradation assessment in states and small countries, such as California, Missouri, and Haiti (1991-1993)
- Demonstrate application of methods on a national scale, such as the United States and Pakistan (1993-1995)
- Use new sensors as available, including Landsat-6 and -7, MOS-1,* ERS-1,* and HIRIS*
- Make available a directory/cataloging capability for the information system (1993-1995)

1996: Operational Information System Phase

- Identify new technologies needed (as SPOT-3,-4) and continue to update requirements
- Provide global maps of specific land degradation components on a scale of 1:5,000,000 for each year, 1990 and 1995, and annual maps of sample sites at 1:24,000 to 1:100,000 for 1991-1996
- Provide stable, tested baseline and methods for identifying significant changes in land conditions on all scales, local to global

*AVHRR: *Advanced Very High Resolution Radiometer*
ERS-1: *First Earth Remote Sensing Satellite (Europe)*
HIRIS: *High Resolution Imaging Spectrometer*
MOS-1: *Marine Observation Satellite (Japan)*
MSS: *Multispectral Scanner*
TM: *Thematic Mapper*

kinds of changes are occurring, and how to preserve and increase productive capacity. Salinization, desertification, and erosion constitute the three processes most implicated in degradation and loss of arable land globally over the past 10 years. Total accumulated losses of arable land from these processes is enormous; globally, more than 950 million hectares may be affected by saline degradation alone. All three processes are capable of being predicted and corrected.

Spaceborne systems are ideally suited for monitoring global land cover and quantifying its areal extent. Remotely sensed data, combined with spectral, spatial, field, and laboratory measurements, will be used to quantify, understand, and forecast land degradation patterns with accuracy and precision. Increased knowledge can save not only resources, but allow more effective use of the enormous sums of money now being spent by national and international funding agencies to improve arable land—efforts that may actually cause or exacerbate land degradation processes.

Objective: Renewable Forest Resources

The objective by 1995 is to provide global mapping of forested versus nonforested areas every 5 years at scales of 1:1,000,000 with 1-km accuracy and local mapping of forest production and yield estimates every year at scales of 1:24,000. Local mapping in sample U.S. locations will include conifer, uplands deciduous, wetlands deciduous, and mixed conifer-deciduous stands of trees. Techniques and models will be developed and demonstrated for extracting information from remote sensors and merging disparate data bases. These new techniques are expected to provide 20-percent improvement in accuracy over current methods of estimating wood production and yield at different latitudes.

AID

Weyerhaeuser Corp.

The global mapping of forests done in this project will, for the first time, use remote-sensing technology to provide a standard for measuring and monitoring worldwide forest distribution and how this is changing. Such knowledge is extremely important for improving worldwide management and utilization of wood resources. Currently, worldwide demand for wood is increasing in the face of a shrinking land base. Demand for wood products in this country alone may increase an estimated 300 percent between 1970 and 2000.

Being able to quantify and more accurately estimate local vegetation production and yields will be of commercial value to the forestry industry and to many other groups, including local governments, scientists, and others concerned with environmental quality and wildlife. Further, an urgent scientific need exists for quantifying more accurately the effects of forests on the global environment.

The projected information system will be compatible with small users' computer infrastructure, allowing private companies to tap into the system for data and catalogs while using their own proprietary yield and growth models on their individual management information systems. The system will require no unusual training needs on the part of users, except possibly initial introductory training for data types generated by new sensors.

Combining strong efforts by the academic community with the private forest service industry represents a significant advantage of this plan. Lack of models and algorithms has been a major deterrent to use of remotely sensed images in this field; the projected demonstration provides many opportunities for combined activities by NASA, universities, private sector commercial users, and possibly international participants.

American Forestry Council

Forest Demonstration

The Steps

1988-1990: Global Map Generation/Data Base Construction Phase

- Acquire two basic imagery data sets for global forest map: leaf on/summer and leaf off/winter
- Collect global data with NOAA's AVHRR and global samples with Landsat and SPOT* sensors (2 years)
- Conduct archive/catalog activity (gather/ digitize representative map bases and enter into geographic data base)
- Prepare global map in 1990, to be updated at 3-5 year intervals

1988-1991: Site-Specific Wood Volume/Data Base Construction Phase

- Collect satellite data annually for quantification of wood volume, density, and productivity at five selected U.S. sites
- Develop algorithms/models of volume density, canopy reflectance, and productivity related/correlated with spectral responses and classification results
- Merge satellite data with related information and digitized maps on vegetation cover types, topography, climate, and national boundaries
- Conduct supporting systematic field measurements from fixed points and enter into geographic data base

1991-1993: Site-Specific Wood Volume/ Revised Estimates

- Collect satellite data annually at five selected U.S. sites for revised estimate of wood volume, density, productivity
- Conduct ground measurements annually for assessing accuracy of remote-sensing methods
- Beginning in 1992, use experimental NASA AIS* data twice yearly over subsites in five sites for signature generation and algorithm/model development

1994 and Beyond: Operational Information System Phase

- Identify new technologies for both global and site-specific mapping (as HIRIS/SAR* data) and continue to upgrade requirements/statistical precision of predictions
- Provide updated (1995) global map of forest/ nonforest areas at 1:1,000,000 scale
- Provide yearly volume estimates and yield predictions for broad forest species groups, with local maps at a scale of 1:24,000
- Offer tested methodology for extracting information from remotely sensed data and reliable quantitative techniques for predicting forest conditions, growth, and yield

**AIS: Airborne Imaging Spectrometer*
SAR: Synthetic Aperture Radar
SPOT: Systeme Probatoire d'Observation de la Terre (France)

The Vision: A Renewable Resources Information System For 1996 and Beyond

What Will It Do?

- Provide users with information to facilitate measurement and understanding of land surface problems throughout the world, with data sets routinely available within 30 days on magnetic tape or optical disks
- Make available land data on different scales and formats, from 1:24,000 for local sites to 1:5,000,000 for national, continental, or global estimates; temporal data will reflect the periodic seasonal changes inherent to erosion, salinity encroachment, desertification advances and forest growth patterns
- Provide geocoded, digitized data, change-detection and other models and algorithms, and related information permitting users to monitor, quantify, and forecast the status and evolution of arable land and forests on a national level
- Offer repetitive coverage of land areas, with ability to examine data within the context of multiple physical and biological parameters, such as cloud cover, climate conditions and change, topography, soil types and characteristics, and human/animal populations
- Provide an easily used information system compatible with microcomputers, permitting flexible and economic access by small users for their varying needs from simple catalogs to data analysis techniques to satellite images merged with other data

Who Will Use It?

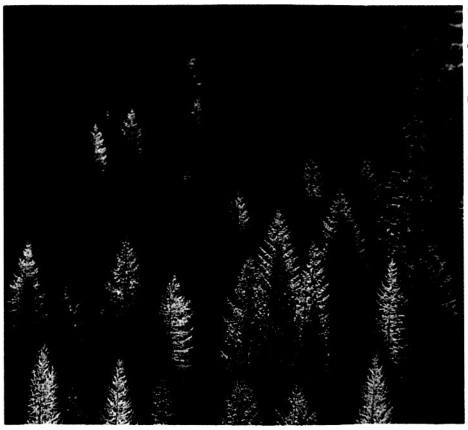
- Government agencies responsible for land, water, and environmental management at Federal, State, and regional levels (USDA's Soil Conservation Service [National Resource Inventory], Agriculture Research Service, and Forest Service; Environmental Protection Agency; Bureau of Land Reclamation; and others)
- Local government entities (e.g., irrigation districts)
- University researchers and environmental scientists
- Private companies (land engineers, land management organizations, U.S. and international timber companies, agribusiness)
- Conservation and recreation agencies and groups
- International groups (World Bank, World Resources Institute, U.S. Agency for International Development, relief organizations)

How Will It Be Used?

- To quantify the areal extent of desertification and to predict and modify the growth of desert areas
- To better plan and manage water resource projects that require regional and global management
- To establish methods of detecting salinity intrusion early enough so corrective measures can be taken
- To monitor the progress and success of reclamation and restoration of damaged land areas
- To identify and assess the degree/extent of erosion on a local to global basis and provide maps and statistical data for corrective measures
- To provide a standard for measuring and monitoring changes in global forest distribution
- To help define and understand the changes and impact of forests and forest management practices on wildlife resources, land use, and climates
- To support local mapping of vegetation production and yield estimates and improve information on forest inventory, forest fire and timber management, forest pest detection and control, and the relation of land use practices to timber production

Tim McCade/Soil Conservation Service

AID



American Forestry Council

Objective: Nonrenewable Resources

The objective by 1993 is to develop and validate new information extraction techniques needed for evaluating potential occurrences of strategic, nonrenewable resources on a global basis at a 1:50,000 scale. U.S. industry and national security are critically dependent on some 34 strategic raw materials used in the manufacture of such high-technology products as jet engines, advanced performance aircraft and spacecraft, electro-optics, and computers. About half of these essential commodities, which are needed to produce corrosion-resistant alloys and semiconductor materials, do not occur within the United States in sufficient quantities to be economically mined and processed. Western world countries are highly vulnerable to a reduced supply of these materials.

Remotely sensed data, combined with conventional types of geological and geophysical data, offer extraordinary promise as an efficient and less costly method of evaluating the potential occurrence of strategic minerals. Satellite methods could provide particularly efficient techniques for mineral exploration in remote and inaccessible areas of the world.

This objective aims to demonstrate how remotely sensed data can be used on a routine basis to assess the regional potential for strategic mineral occurrences. The resources selected for this demonstration—chromium, cobalt, manganese, and platinum-group metals—represent commodities of the highest priority to the United States; these minerals are almost exclusively produced in South Africa, Zaire, and the Soviet Union.

The project is designed to develop and demonstrate techniques for extracting information and merging the disparate data sets useful for evaluating strategic mineral occurrence. The demonstration will expand the community of geologists who can successfully use sensor data in the 1990s, because it offers many researchers the chance to access and manipulate a wide variety of digital data bases in a highly interactive fashion. Because geologists commonly archive and transfer information in the form of paper maps and film transparencies, they tend to be unfamiliar with the manipulation and merging of large quantities of digital data.


MacKay School of Mines

Strategic Minerals Demonstration

The Steps

1988-1990: Initial Data Collection/Data Base Construction Phase

- Identify six test sites (about 20 user groups)
- Collect data over test sites, using existing orbital sensors (Landsat's MSS, TM, ETM* and SPOT's XS* and PN*), and NASA experimental aircraft sensors (AVIRIS,* TIMS,* and SAR)
- Georeference the various data sets, including conventional forms of geological and geophysical data, to common map projection; place in data bases
- Calibrate data sets with ground and laboratory spectra for each site

1991-1993: Commodity Evaluation Phase

- Evaluate the likely occurrence of specific commodities at individual foreign and domestic test sites (about 100 user groups, each at a separate site or node)
- Use new commodity occurrence models to evaluate likely presence of test commodities in a variety of physical environments, such as tropical, temperate, semi-arid terrain
- Analyze data; develop three-dimensional models, using remotely sensed and conventional forms of geological/geophysical data combined with geological models

1994 and Beyond: Operational Information System Phase

- Have prototype information system ready for use by exploration geologists to evaluate strategic minerals, with mineral potential maps available at a scale of 1:50,000
- Begin production of routine data sets for the information system, using sensors on the NASA/NOAA Polar Platform (scheduled for launch in 1995) and/or sensor systems flown by commercial operators
- Expand system from being site and time specific to multitemporal in scope

* *AVIRIS: Airborne Visible/Infrared Imaging Spectrometer*
ETM: Enhanced Thematic Mapper
PN: Panchromatic
TIMS: Thermal Infrared Multispectral Scanner
XS: Multispectral Scanner


National Marine Fisheries Service

The Vision: A Nonrenewable Resource Information System for 1996 and Beyond

What Will It Do?

- Use extraction techniques routinely from sensors on the NASA/NOAA Polar Platform to evaluate potential occurrences of strategic raw materials on a global basis
- Provide users with existing archived data sets routinely within 1 week, and with new data sets to be acquired by orbital sensors within 2 weeks
- Provide digitized, geocoded data, information, algorithms and models, and related services to a technically diverse, geographically scattered community of users, using telephone-based communications, mailing of magnetic tapes or optical media products or, if then available, using real-time microwave or fiber optic communications
- Provide such ancillary information as catalogs of geological/soil maps, digital topographic data, digital gravity and magnetic survey data, geochemical surveys, spectral libraries defining the spectral and radiometric properties of common surficial materials, U.S. and foreign petroleum well data bases, and digital cultural information
- Provide a well-documented, menu-driven, and user-friendly service with embedded "help" information, with reasonable costs to the user dependent on level of service and demand

Who Will Use It?

- Academic geologists
- Exploration geologists, U.S. mining industry, and industrial sector
- U.S. Federal government (Department of Interior, Department of Defense, national intelligence and security agencies)
- Geological engineers

How Will It Be Used?

- To conduct comparative studies of mineral occurrences in different parts of the world and develop improved models of mineral formation in the Earth's crust
- To identify and assess (through algorithms and models) probable sources of base and precious metals, oil and gas, coal, and uranium, and to target such areas for detailed ground-based exploration prior to drilling
- To identify alternative sources of supply of strategic materials and strive to foster friendly bilateral relations with countries that harbor such supplies
- Use adaptations of the proved techniques to identify sites for waste disposal and dam construction and to define environmental baseline conditions for establishing land reclamation requirements

OCEAN/ATMOSPHERE

During the last decade, short-range weather forecasts have become vastly more accurate as a result of satellite-based global observing systems. Satellite observations in the visual and infrared parts of the spectrum now routinely monitor weather systems virtually impossible to identify by in situ measurements, such as convective storms, frontal systems, tornados, and hurricanes. The short-term storm warnings now possible are saving lives and appreciably reducing property and agricultural damage. Considerable potential still exists for improving the accuracy and the length of weather forecasts, which would be valuable for a wide range of users. In addition, new ocean sensors flying in the early 1990s, such as wind profilers, will generate types of information not previously available.

In the ocean/atmosphere area, a program of research on four-dimensional data assimilation schemes is recommended. The planned program will integrate all available germane observations, with the aid of appropriate models, to make full four-dimensional field estimates for the first time for oceanography and meteorology. Applications demonstrations in the ocean/atmosphere area will focus on the oceanic mesoscale, atmospheric long-range weather, and the short-term climate scale. From the standpoint of applications, the ability to predict natural climate variability on time scales of weeks to several years offers enormous social and economic benefit for forecasting crop yields, ocean productivity, droughts, and severe winters. The activity will also significantly enhance the ability of scientists to understand air-sea interactions and the basic physical and dynamical processes of the global atmosphere, which affect weather prediction and climate.

In both the ocean and atmosphere areas, large government-owned and operated, integrated systems of data handling exist within operational agencies. There is a major need—addressed by this applications strategy—to link these operational facilities with NASA's research centers and with the external research community for the purpose of improving forecasts. Such linkages between NASA, operational agencies, and researchers are created during the demonstration phase of the ocean/atmosphere applications strategy. At a later stage, the very large potential user community will gain access to the gridded data fields.

The ocean/atmosphere objectives offer the following significant advantages:

- The approach provides a mechanism for linking NASA's research data and skills with the major operational agencies, in particular, making available to NOAA the high level of NASA expertise in developing geophysical algorithms and modeling global atmospheric circulation
- The approach helps to define an ongoing research role for NASA within the operational systems
- Additional research capabilities, such as those of the National Science Foundation (NSF) and several universities, will become available within the system for NASA research and for operations and applications users
- The approach identifies specific types of operational data, not now archived, which need to be preserved for both science and applications purposes, including NASA research
- The demonstrations and information system will quickly provide users with electronic links and access to badly needed data from new ocean sensors that will fly in the early 1990s

Objective: Ocean (Hindcast, Nowcast, and Forecast)

By 1995, the ocean objective is to define and validate an operational hindcast, nowcast, and short-term (up to 1 week) forecast system with mesoscale resolution for a number of oceanic and atmospheric planetary boundary layer physical variables. The nowcast will be available hourly in a 2-km grid size on a regional (ca. 1,000-km sq.) basis and daily on a global basis in 100-km grid size, with state-of-the-science accuracies for oceanic surface temperature, currents, wave height, atmospheric temperature, surface winds, and related variables.

The Ocean Information Subsystem will for the first time incorporate government and university research data generated by both NASA and NSF. These data will be available in near real time, with products related to ocean currents and ice available within 24 hours. Both scientific research and practical applications can benefit from the calculation of comprehensive fields of oceanic/atmospheric boundary layer information made possible by the project.

Several global-scale questions of concern to the Earth system sciences can be addressed by this subsystem, including atmosphere-ocean momentum, heat and moisture transfers, and carbon dioxide assimilation by the oceans. These same transfers are critically important in climate analysis and forecasting. A cascade of follow-on specific applications will be possible. As an example, the proposed subsystem will replace current, relatively subjective ship routing techniques with skillful predictions over 1 week, allowing mathematically based, objective optimum-track routing for ships on crossings in both the Northern and Southern Hemispheres. Comparable systems are ready to be implemented in the fields of marine resource management and extraction.

National Marine Fisheries Service

Ocean Demonstration

The Steps

1987-1989: Algorithm/Model Development Phase

- Assemble and evaluate atmospheric and oceanic boundary layer models
- Assemble and evaluate relevant geophysical data retrieval algorithms
- Design and develop four-dimensional data assimilation schemes

1989-1991: Test/Evaluation Phase

- Test and evaluate four-dimensional data assimilation schemes against NOAA, Seasat, and other data sets, model-simulated fields, and field experiments
- Design and plan prediction experiments in applications areas of atmospheric visibility, fog, icing, and oceanic frontal developments; conduct studies of systems' sensitivity to input variables and the range of accuracy and resolvable scales

1991-1993: Regional/Regime Experiments

- Conduct prediction experiments in a variety of regions (off the East Coast, West Coast, Gulf Coast, Marginal Ice Zone), showing capability to meet performance measures in all seasons
- Utilize N-ROSS, TOPEX, ERS-1 data sets
- Include periods of week-long forecasts by 1993

1993-1995: Demonstration Phase

- Conduct demonstrations using detailed test plan (test nowcast assimilation algorithm against existing operational systems, using all operational data sources and new TOPEX, ERS-1 research data)
- Test accuracy of algorithm by in situ experiments of international ocean research programs
- Demonstrate prediction system in U.S. Exclusive Economic Zone for 1 year (1995)

1996: Operational Information System Phase

- Complete test of accuracy in statistically significant number of cases in different seasons and geographic areas
- Create hourly values of variables within 1 day on a regional basis (ca. 1,000 km sq.) and daily on a global basis
- Show capability for ongoing stable, routine performance without extensive manual intervention and well-defined, routine outputs
- Complete training in use of product streams for personnel at operational centers
- Demonstrate system simplicity and ease of access to encourage use by groups with varying expertise

Atmosphere Demonstration

The Steps

1987-1991: Four-Dimensional Data Assimilation Algorithm Development

- Develop global four-dimensional data assimilation algorithm with
  - parameters having defined accuracies
  - given spatial grids
  - defined times
- Demonstrate various system modules by 1991 to peer review group

1991-1992: Demonstration Phase

- Test proposed climatology assimilation system against existing NOAA/NMC operational system
  - develop grids of parameters produced by assimilation algorithm
  - test accuracy by special validation data sets
  - test system performance in various regimes of weather

1991-1995: Long-Range Research Forecast Experimental Phase

- Develop weekly and monthly mean temperature and precipitation
  - measure forecasts by defined skill scores
  - test system by comparing errors against current forecast system
  - test system by comparing errors against results from assimilation algorithm at end of forecast interval
- Initiate demonstration phase for improved long-range forecast skills (1995)

1993 and Beyond: Operational Information System Phase

- Begin operational use of atmosphere information system based on four-dimensional data assimilation
- Make adjustments to experimental long-range forecast system (1996)
- Show simplicity and responsiveness of system for potential users

Objective: Atmosphere (Four-Dimensional Data Assimilation)

The atmosphere objective is to develop and validate by 1993 an atmospheric information system that will provide weekly, monthly, and seasonal values of such climate parameters as temperature, humidity, rotational and divergent components of the wind, soil moisture, ice and snow cover, precipitation, and surface and atmospheric albedo. Using a process of four-dimensional data assimilation, these values will be provided globally at one-degree latitude/longitude intervals.

The essential purpose of the atmosphere plan is to improve the current level of skill for extended-range weather and climate forecasts. This capability will foster research on fundamental atmospheric processes, which are vital if we are to understand and differentiate important man-made changes in climate from natural variations. Techniques developed in the plan can help to explain the sensitivity of climate to external forcing and to validate models for predicting global climate and change, issues considered of crucial concern by ESSC.

This atmosphere objective uses the existing atmospheric information system, with the lead role assumed by NOAA's National Meteorological Center (NMC). An important advantage of the plan is that it sets up a cooperative research structure between NOAA and NASA—a fusion increasingly vital as the Eos Space Station era approaches, with its Polar Platforms combining research and operational sensors. The full report of the Working Group suggests a model for continuing NASA/NOAA cooperation that encompasses shared research activities, transfer to the operational stage, and ongoing efforts to improve algorithms and models in parallel with operational experience.

NOAA

Michael J. Keating

The Vision: An Ocean/Atmosphere Information System for 1996 and Beyond

What Will It Do?

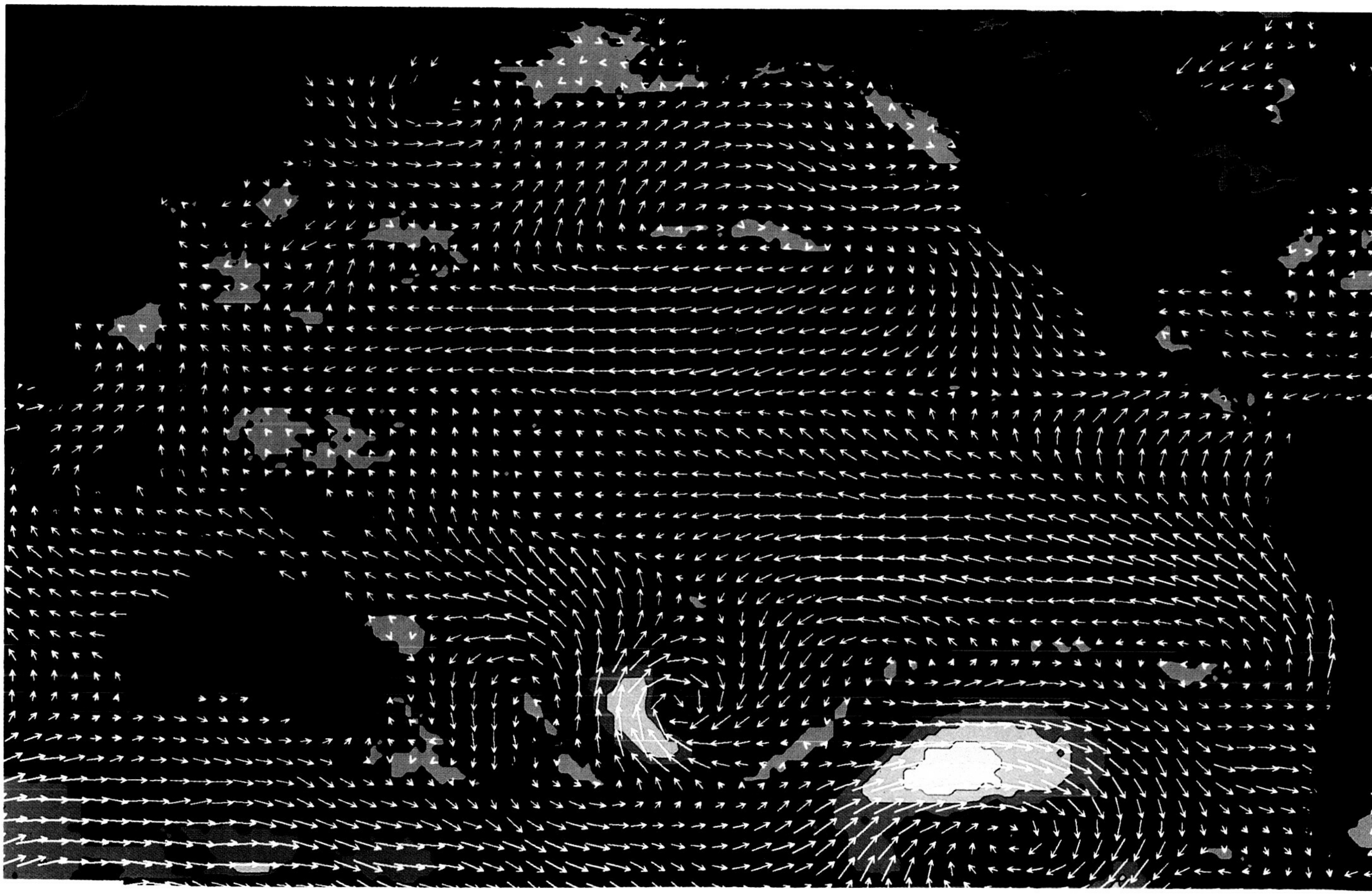
- Provide global dynamic predictions of weekly and monthly mean temperatures and precipitation
- Provide nowcasts of temperatures, humidity, wind, etc. by 1 day after end of work week
- Provide 30-day forecasts of temperature and precipitation available within 2 days after the end of each month
- Provide hourly values for ocean/atmosphere boundary layer variables within 1 day on a regional basis and daily on a global basis
- Function as responsive on-line system to a variety of users, with directory of NOAA environmental satellite and other data, a query-based catalog, and browse file with sample data
- Provide from NASA a project bulletin board, standard algorithms library, and communications networks
- Provide ordering function with delivery via magnetic tape

Who Will Use It?

- Operational centers
- Researchers
- End users (value-added weather forecast firms, agricultural planners, marine operations, offshore exploration/development, planners for energy/water, airlines industry, recreational boating, tourism industry)
- Federal agencies (U.S. Geological Survey, U.S. Coast Guard, Minerals Management Service, Army Corps of Engineers, Maritime Administration)

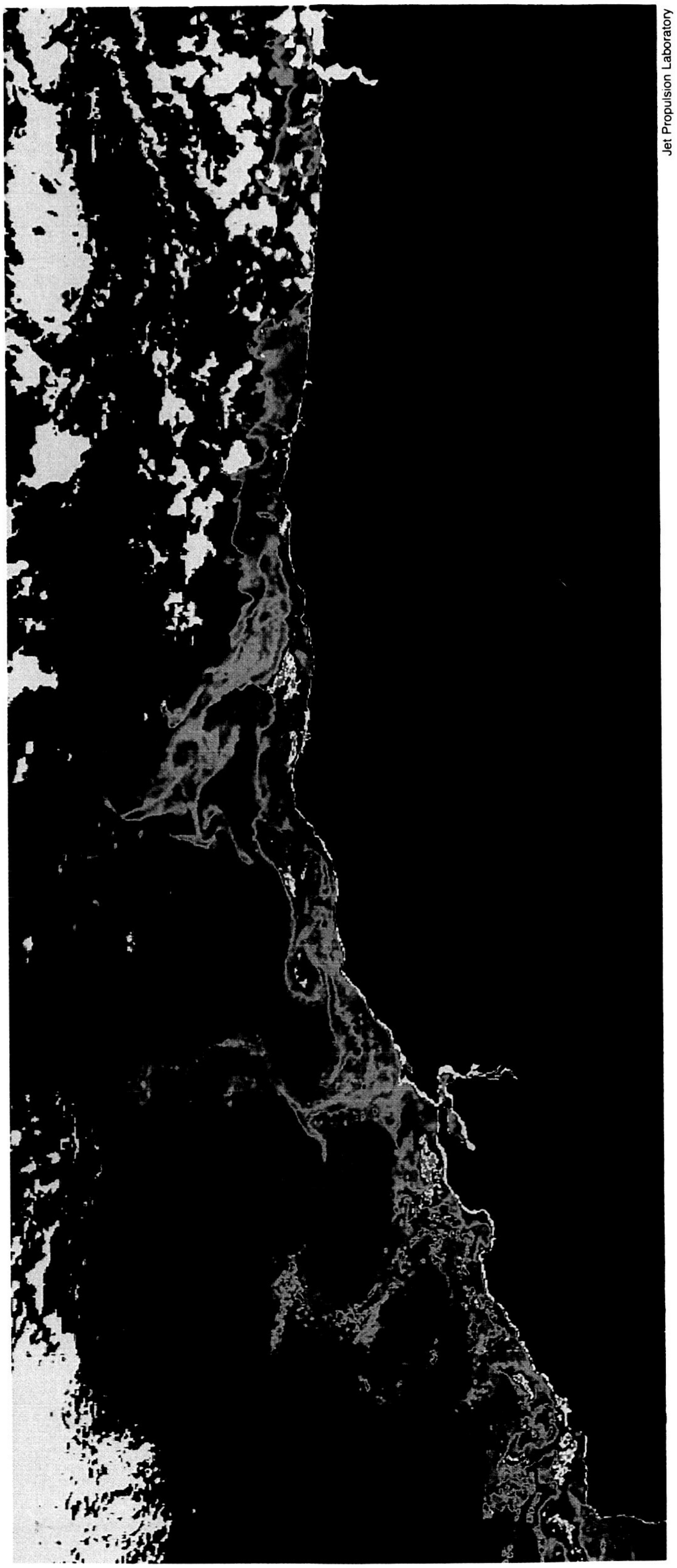
How Will It Be Used?

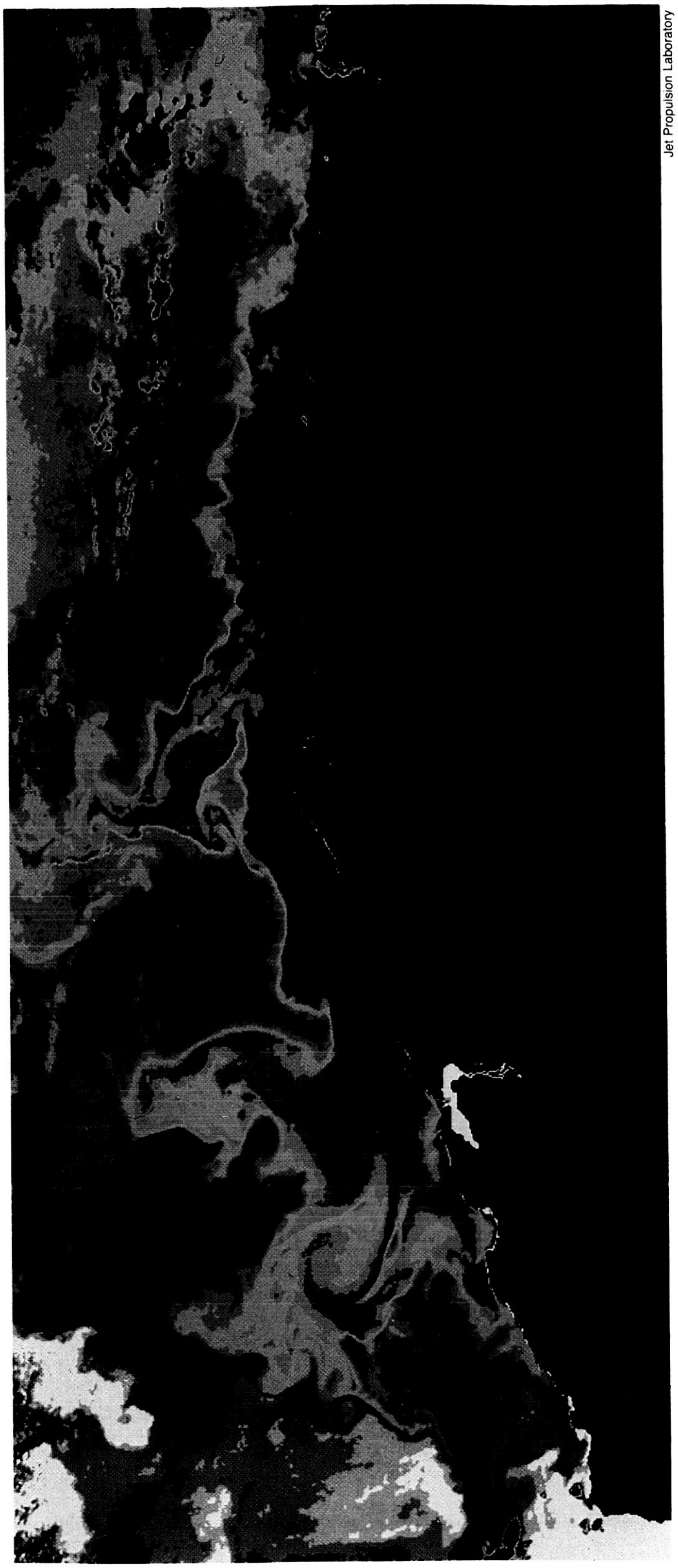
- To provide techniques and algorithms for operations data assimilation and forecasting
- To provide information products and new algorithms for research purposes
- To provide concrete retrospective/present/forecast information products for
  - search and rescue operations
  - improved extracting and management of marine resources
  - general marine operations
  - oil spill dispersal estimates
  - ocean dumping assessments
  - ship routing
  - marine weather forecasting
  - fishing operations
  - pollution monitoring
  - offshore well drilling and maintenance
  - sea-ice monitoring



Jet Propulsion Laboratory

Sea-surface winds affect the exchange of heat between the atmosphere and the ocean. Past observations of marine winds have been collected by ships and have therefore been limited in both area and number. The Pacific Ocean segment, above, of a global windfield map for September 6-8, 1978 was produced from measurements derived from the radar scatterometer (arrows show wind directions; large arrows indicate greater wind speed).





Coastal surface waters offshore, where there is an upwelling of cooler subsurface water, are among the most productive ocean regions for harvesting fish. These satellite images, taken 8 hours apart, represent West Coast sea-surface temperature (right) and phytoplankton chlorophyll pigment concentration (left).

Images were derived from infrared temperature readings of the Advanced Very High Resolution Radiometer and from ocean color measurements of the Coastal Zone Color Scanner.

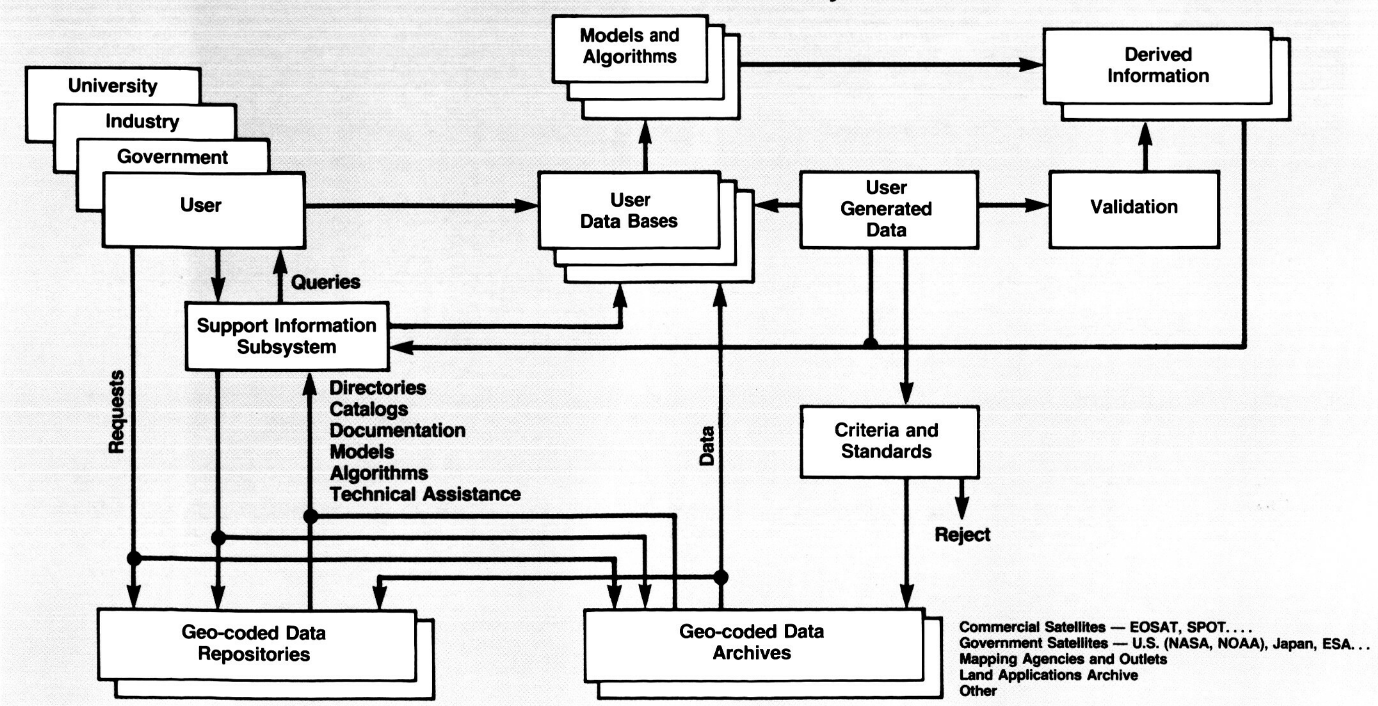
5

Information System Architecture

It is both possible and advantageous to fold all applications, current and future, under the umbrella of a single information system. This system would employ common elements where possible, but separate elements where indicated by agency or technological constraints. One of the common elements should be many of the support services, including the data directory, catalog, and inquiry system. Even though applications vary so widely, many use similar data sources, require similar user support functions, and share similar methodologies for investigators, such as requiring the geocoding of remotely sensed imagery. The proposed architecture consists of common core functions plus two subsystems—one for land resources and one for ocean/atmosphere.

The Applications Information System is designed to be developed in a gradual evolutionary manner, with its features driven by the specific applications selected by NASA now and in the future. Such an evolving system fosters rather than precludes the inclusion of future technical capabilities, and it can be started early on a modest scale. A modular approach is envisioned for building the system, with structured interfaces to aid in providing future expansion, transfer to future operators, and future research. To the greatest extent possible, readily available components, including equipment, software, and technologies, will be utilized. This type of cohesive, integrated approach to building the system offers the following advantages:

Figure 1
Resource Information Subsystem



- Less ultimate overhead cost in terms of personnel and logistics
- Decreased time required to build, lessening the risk of scheduling delays and cost escalation
- Improved ability to incorporate new technologies as they become available
- Simplified transfer and replication of techniques for those taking over operations after the demonstration period ends
- Increased transferability to ultimate users
- Facilitation of broad disciplinary and interdisciplinary studies

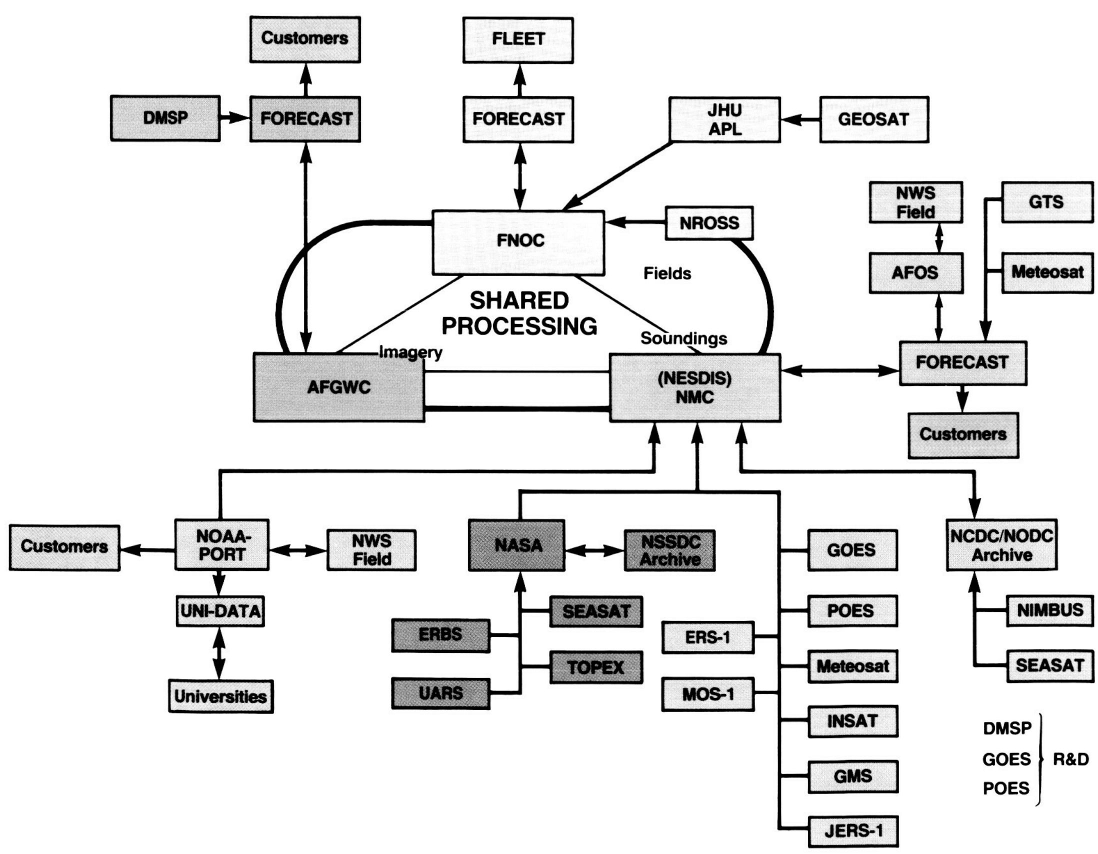
The Applications Working Group recommends that NASA set up an oversight committee at the start-up of planning for the Applications Information System. This oversight committee should consist of industry, government, and university members representing both applications and the technological disciplines. In developing the system, data formats, software, and interface protocols should follow the existing and emerging standards for space science data management recommended by national and international bodies, such as the National Academy of Science's Committee on Data Management and Computation. The system can be expanded to serve the Eos program when it becomes operational.

Users will have access to the system through either standard computer terminals or commercial telephone lines. Among the common functions planned are central directories, catalogs, browse files, a bulletin board and message exchange, inquiry and connecting networks, applications-independent software, technical assistance, and ordering capabilities.

LAND RESOURCES INFORMATION SUBSYSTEM

This subsystem is designed to serve end users, since large satellite operational systems do not carry dissemination responsibilities in the land resources area. The information system requires geocoded data and places heavy emphasis on imagery. Architecture for the Land Resources Information Subsystem is shown on Figure 1 *(see p. 21)*. The central feature of this subsystem

Figure 2
Ocean and Atmosphere Information Subsystem Currently Planned Network



KEY TO ACRONYMS:

AFGWC	*Air Force Global Weather Control*
AFOS	*Advanced Field Operations Systems*
DMSP	*Defense Meteorological Satellite Program*
ERBS	*Earth Radiation Budget Satellite*
ERS-1	*First Earth Remote Sensing Satellite*
FNOC	*Fleet Numerical Oceanography Center*
GEOSAT	*Geodesy Satellite*
GFDL	*Geophysical Fluid Dynamics Laboratory*
GOES	*Geostationary Operational Environmental Satellite*
GMS	*Geostationary Meteorological Satellite*
GSFC	*Goddard Space Flight Center*
GTS	*Global Telecommunications System*
INO	*Institute for Naval Oceanography*
INSAT	*Indian National Satellite*
JHUAPL	*Johns Hopkins University Applied Physics Laboratory*
METEOSAT	*Meteorological Satellite*
MOS-1	*Marine Observation Satellite*
NCAR	*National Center for Atmospheric Research*
NCDC	*National Climate Data Center*
NEDRES	*National Environmental Data Referral System*
NESDIS	*National Environmental Satellite Data Information Service*
NMC	*National Meteorological Center*
NODC	*National Oceanographic Data Center*
N-ROSS	*Navy Remote Ocean Sensing Satellite*
NSF	*National Science Foundation*
NSSDC	*National Space Science Data Center*
NWS	*National Weather Service*
POES	*Polar-Orbiting Operational Environmental Satellite*
TOPEX	*Ocean Topography Experiment*
UARS	*Upper Atmosphere Research Satellite*

LEGEND:

- U.S. Navy Operational System
- NOAA Operational System
- U.S. Air Force Operational System
- NASA Experimental Programs
- Customers and Users

will be the data bases created by investigators for each test site, consisting of remotely sensed and in situ data that have been merged and manipulated to derive the desired information. Other types of data related to the test sites may also be included, such as climatic conditions, topography, geology, vegetation cover, land use, and water table depth. Investigators will generate and provide special data sets if they are needed for the models.

Primary input to the data bases will come from geocoded data repositories and archives, including many U.S. and foreign land remote-sensing satellites as well as other existing land data archives. Initially, real-time data will not be required, but the system offers this capability if needed in the future.

NASA will need to define access procedures for proprietary commercial and other controlled data; such procedures should be mutually agreeable to the government and to private interests.

OCEAN/ATMOSPHERE INFORMATION SUBSYSTEM

In the ocean/atmosphere area, the subsystem emphasizes gridded digital data. Figure 2 shows the three-agency operational system, which is expected to be in existence by the end of this decade. This system of coordinated environmental services is currently budgeted, based on an understanding among the three agencies that involves atmospheric soundings, ocean parameter fields, and cloud and surface imagery. The figure shows the linkages among the three agencies (FNOC, AFGWC, and NMC) with associated government and university research programs, including NASA experimental programs and university programs linked by NSF's Unidata system.

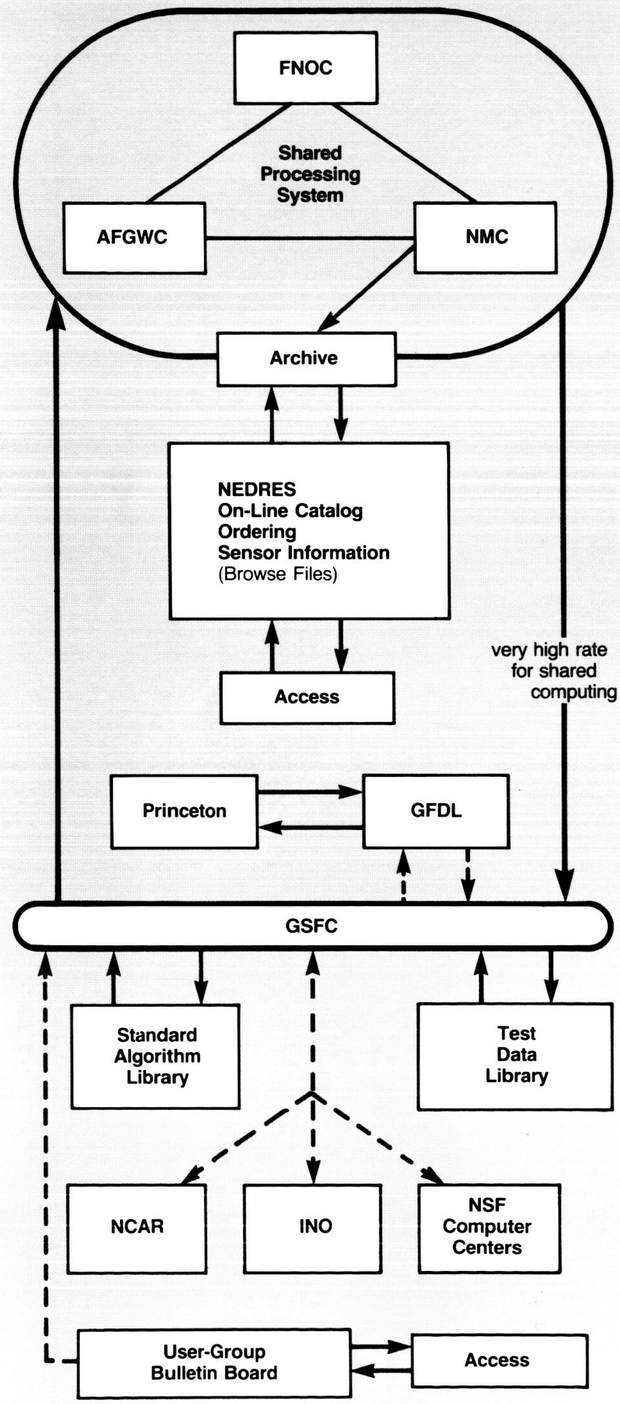
The objectives in the applications demonstration require adding to this system a very high rate link for computer sharing between the NMC and Goddard Space Flight Center (GSFC) and two libraries at GSFC—one for standard algorithms and one for test data (see Figure 3 for the minimal configuration needed initially). Data on magnetic tape will be distributed to users by these libraries. Several other centers and universities will be associated with the program. Initially, these centers will receive data from the central user services by magnetic tape.

INFORMATION SYSTEM RECOMMENDATIONS

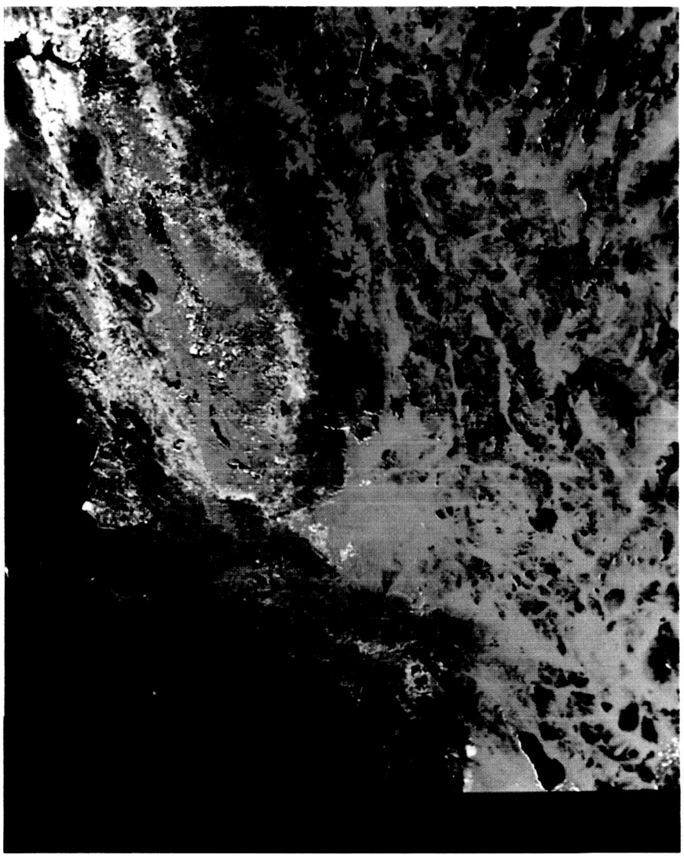
In connection with start-up and evolution of the proposed strategy, the Working Group recommends that the Applications Information System should

- Include a central support information subsystem serving both land resources and ocean and atmosphere applications
- Be planned and built following a modular approach, with structured interfaces
- Utilize, to the greatest extent possible, existing commercially available equipment, software, and technologies
- Adopt existing and emerging data format standards, software standards, and interface protocols
- Be planned and executed with active, participative interaction between the researchers, technologists, and the potential future operators
- Contain an oversight function put in place at the beginning of the program

Figure 3
Ocean and Atmosphere Information Subsystem Initial Research and Development Network



Dotted lines show projected future links in final operational network, with GSFC acting as node for high-speed real-time data distribution. The top oval contains the total planned operational capability shown in Figure 2.



Major changes in land conditions over May 10-June 13, 1979 are shown in this geometrically corrected image of California, derived from the Coastal Zone Color Scanner. Changes include reduction in snow pack (dark blue), senescence of green grassland vegetation (orange/yellow), and wildfires (black).

6

Implementation of the Applications Strategy

- *An integrated, expandable Applications Information System*
- *Application research demonstrations important in their own right and as the first trial modules of the new system*

These are guideposts for NASA in setting up their long-term plan for remote-sensing applications. The report of the Working Group helps to focus directions, providing detailed technical milestones for this flexible and forward-looking program. To implement the applications strategy, NASA also will need to deal with a range of other issues specifically pertaining to management, user attitudes, and the selection of applications research proposals.

MANAGEMENT ISSUES

The remote-sensing field is complex, involving many organizations—government operational agencies such as NOAA and Navy; NSF; international scientific bodies; university researchers; end users; and the commercial sector, represented by the EOSAT Corporation and the value-added industry. The applications strategy both includes and serves all these groups, which will require gaining their cooperation and, in many cases, setting up new working agreements. In addition to linking the involved agencies, restrictions will exist concerning what kinds of data can ultimately be included in the information system. The rights of the commercial sector to sell certain types of data without unfair government competition will need to be respected. The proprietary rights of individual companies to retain some types of information will also need to be defined and protected, often on a case-by-case basis within the demonstration mode. Sample issues needing NASA's attention include

- Institutional agreements with EOSAT regarding access to Landsat data and other commercial issues
- Institutional agreements with operational agencies, particularly NOAA, which would include shared personnel and facilities during the development and technology transfer phases
- Agreements with NOAA on retention of data from their observational systems
- Analysis to ensure compatibility of the Applications Information System with the proposed Eos system
- Agreements to conduct ground tests pertaining to minerals on sites in foreign countries
- Agreements for acquiring data from foreign satellites and international projects

USER ATTITUDES

In the present constrained Federal budget climate, users—Federal agencies in need of NASA research expertise or individual private companies—will be expected to share costs or to pay for information products and services. The current environment therefore exacts close communications between NASA and the user community. Remote-sensing services cannot be provided in a vacuum; NASA needs to be assured that the services they develop are meeting a real need for users, that there is a viable market, and that this service will not compete with products available from the private sector.

The Working Group feels great concern about the importance for NASA of involving users at all stages in the development of the Applications Plan. To provide this interface, the Working Group recommends appointment of an oversight committee to help plan the Applications Information System initially and as the system evolves. In addition, a separate working group should advise NASA as each demonstration project is set up and implemented.

SELECTION OF APPLICATIONS RESEARCH PROPOSALS

A framework for helping NASA select participants in the demonstration phases of their Applications Plan has been defined with some care by the Working Group. Participants will be selected through NASA's research proposal program. In a broad sense, all applications

Selection Criteria For Applications Proposals

Public Domain Proposals

- Well-conceived plan for transferring new technology or models
- Well-defined recipient community
- Technologically sophisticated recipients capable of applying results economically

Joint Venture Proposals

- Operational viability and sound proposed business plan
- Compatibility with NASA's intent to advance research goals
- Consistency with national goals for commercialization of space

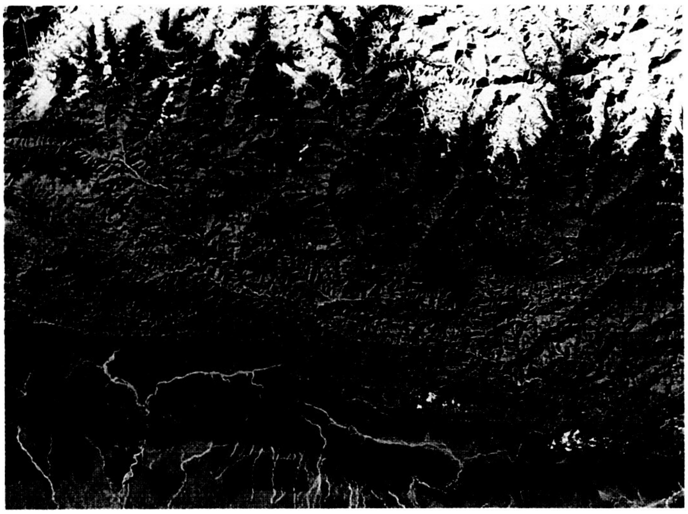
proposals will be expected to forward NASA's goals and objectives as well as to meet national needs. Other questions to be addressed include

- Does the research represent a step forward, needed now and over the long term?
- Will the new techniques or models be flexible and adaptive for diverse applications?
- Is the needed data identified and available?
- Can the proposed technology be used economically?
- Is the state of science in related fields sufficiently advanced to support it?
- Is the research carefully planned on a phased-in basis, with clear-cut intermediate points for review and decisions?

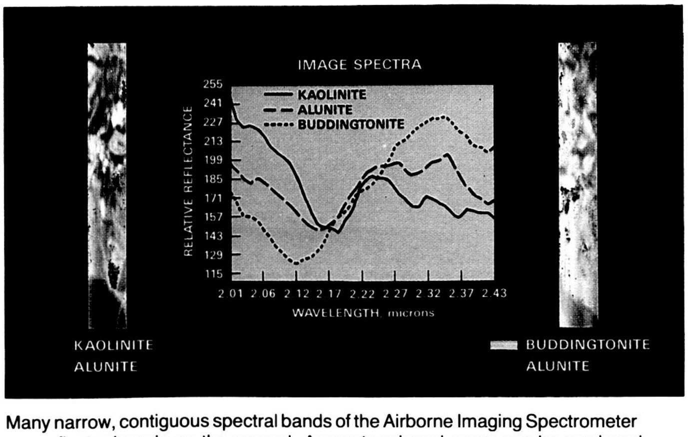
Applications proposals will be divided into two categories: (1) public domain proposals submitted by Federal agencies, universities, or the private sector, and (2) commercial joint venture proposals usually submitted by private sector and university researchers. For commercial joint venture proposals, applicants will be expected to share costs with NASA. These proposals address commercial rather than research objectives, and are aimed at enhancing a commercial product or service.

Jet Propulsion Laboratory

This Thematic Mapper image of the Silver Bell copper mine illustrates how multispectral data can be used to locate mineral deposits. Clay minerals (orange) are associated with copper deposits.



Satellite image of the Himalayan Mountains.



Jet Propulsion Laboratory

Many narrow, contiguous spectral bands of the Airborne Imaging Spectrometer can reflect minerals on the ground. Accurate mineral maps can be produced in seconds from such images and their derived spectral reflectance curves.

7

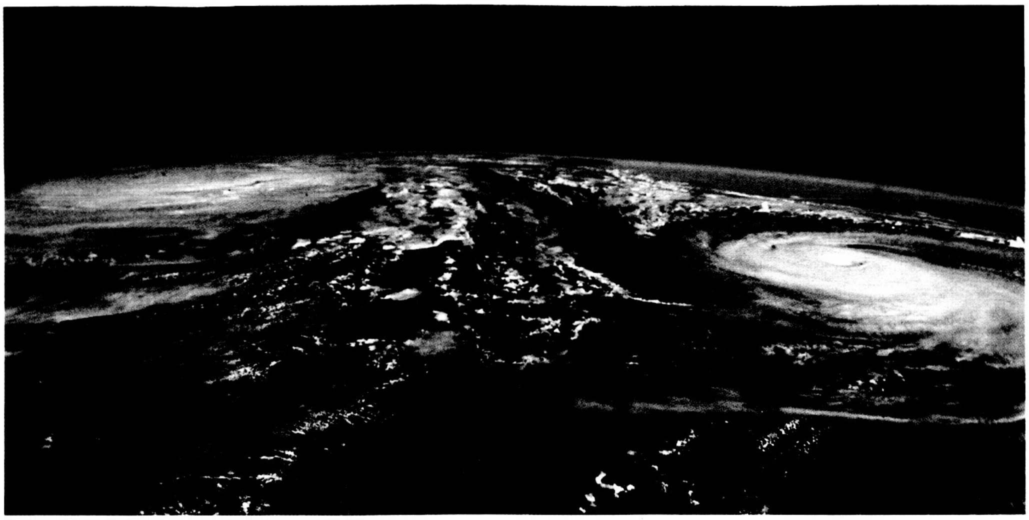
Conclusion

The proposed Applications Strategy fosters and encourages use of space data to resolve a myriad of practical problems affecting mankind's survival on Earth, as well as to provide help with the daily decisions affecting individuals' livelihood in many fields. It is a flexible approach that will start serving users quickly, yet can change and grow to meet challenges of the future as we discover new applications not yet dreamt of.

This strategy takes an integrated and balanced approach, addressing the different needs of users in all Earth-observation fields. It offers the chance to acquire knowledge important for both science and applications and is coherent with the new multidisciplinary global approach to understanding the Earth. This strategy forges a link between NASA's extraordinary research skills and capabilities and those who need this expertise, both for routine system operations and for use by individuals possessing all levels of sophistication.

Thanks to years of superb research and engineering development by NASA, the United States harbors the most advanced space technology in the world. We need to bridge the widening gap between our technological capability and the practical uses we make of it. This Applications Strategy will help NASA to promote the use of space-based data both for economic gain and for the improved welfare of mankind.

William Aliff/AFC



This image made by the Space Shuttle Discovery captures the first paired typhoons photographed from space, Odessa (left) and Pat (right).

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SIGNIFICANT ACHIEVEMENTS

1960 TIROS-I/Broadband Visible Imagery
Visualize weather patterns (clouds)
Tracking tropical cyclones
Day/night infrared imagery
Surface temperatures

1963 First Automatic Picture Transmission (APT)
TV Direct Read-Out

1966 ATS Spin Scanning Camera
Continuous cloud tracking
First continuous satellite communications
Continuous tracking of severe weather (Cyclones and convective storms)

1967 First Infrared Sounder
First global temperature soundings

1968 GEOS
First ocean altimeter/first global geoid measurement

1970 Nimbus-4
First global ozone profiles

1972 ERTS-1 Landsat High Resolution Imaging
First multispectral surface map

1974 First Visible and Infrared Spin Scanning Radiometer (VISSR) on SMS-1
First geosynchronous day/night infrared observations

1975 Nimbus-6
First atmospheric limb scanner
First global Earth radiation budget

1975 First GOES Operational Satellite

1977 Large Area Crop Inventory Experiment (LACIE)

1977 Automation of Field Operations and Services (AFOS)
First weather distribution system

1978 Microwave Sounder
First all-weather sounding capability

1978 Nimbus-7
First ocean color observations
Scanning microwave radiometer
First ozone daily mapping capability

1978 Active Microwave/Seasat
First ocean surface winds
First ocean current variability measurement
First SAR/internal wave/wave spectra/bathymetry

1978 Heat Capacity Mapping Mission (HCMM)
First apparent thermal inertia maps of the Earth's surface

1978 Solar Maximum Mission (SMM)
First continuous solar irradiance "solar constant" measurement

1978 Stratospheric Aerosol and Gas Measurement (SAGE)
First global aerosol measurement

1980 VISSR Atmospheric Sounder (VAS) on GOES-4
First geostationary temperature sounding

1981 (Class V Computer)

1981 Shuttle Imaging Radar-A (SIR-A)
First land-dedicated imaging radar (L-band penetration in Sahara demonstrated)

1982 NASA-Geosat Test Case Project Completed

1982 Landsat Thematic Mapper (TM)
First high resolution multiwavelength surface measurement
First high resolution thermal infrared observations

1982 (Class VI Computer)

1983 Thermal Infrared Multispectral Scanner (TIMS)

1984 Airborne Imaging Spectrometer (AIS)

1984 Shuttle Imaging Radar-B (SIR-B)
First multiple-incidence angle orbital radar imagery
Three-dimensional radar stereo viewing capability demonstrated for the first time at Mt. Shasta

1985 Measurement of Atmospheric Pollution from Space (MAPS)
First global tropospheric chemistry measurements (carbon monoxide)

1985 Earth Radiation Budget Experiment (ERBE)
First diurnal/global measurements of Earth Radiation Budget

1985 Atmospheric Molecules Observed by Spectroscopy (ATMOS)
First simultaneous stratospheric survey of minor chemical species

1986 First Stereographic Imaging from Space

1986 Systeme Probatoire d'Observation de la Terre (SPOT)
Launched commercial data and stereo imaging

FUTURE SYSTEMS

Advanced Microwave Sounder
All-weather soundings of high resolution

GOES-I (GOES-NEXT)
1-km registration on the ground
Ability to locate weather features to 1 km
Dedicated geosynchronous soundings
Capability to "zoom in" on severe storms

NASA Scatterometer (NSCAT)
Global ocean surface winds (wind speed and direction)

Shuttle Imaging Radar-C (SIR-C)
First multifrequency, quad solarization radar system in space

Upper Atmospheric Research Satellite (UARS)
First comprehensive measurements of stratosphere
Energy inputs/solar ultraviolet
Atmospheric chemical species
Atmospheric dynamics/direct wind measurements

Ocean Topography Mission
First precise global ocean altimetry measurement

Advanced Weather Information Processing System (AWIPS-90)
Advanced work stations
Full digital data to field

(Class VII Computer 100 km Grid for Fields)
Next generation operational global models

High Resolution Infrared Spectrometer (HIRIS)
First high spectral, high spatial resolution images providing detailed coverage of land and inland water surfaces on a small-scale local basis

Polar Platform of Space Station
Simultaneous measurements
Combination of scientific and operational measurements
International participation
Comprehensive information system